Sub D7

What is claimed is:

1. A method comprising the step of annealing at least one region of a semiconductor substrate with a pulsed beam of particles having a time duration less than or equal to 10^{-4} seconds.

2. A method as claimed in claim 1 wherein the substrate includes an amorphous region positioned in contact with the substrate and the particle beam heats the amorphous region sufficiently to convert the amorphous region into a crystalline region with a crystal orientation aligned to the crystal orientation of the substrate due to the substrate acting as a seed for the crystalline region.

3. A method as claimed in claim 1 wherein the particles in the beam include electrons.

4. A method as claimed in claim 1 wherein the particles in the beam include protons.

5. A method as claimed in claim 1 wherein the particles in the beam include ions.

6. A method as claimed in claim 1 wherein the particles in the beam include ionized gas molecules.

7. A method as claimed in claim 1 wherein the particles in the beam include neutral atoms.

8. A method as claimed in claim 1 wherein the particles in the beam include molecules containing a dopant atomic species.

9. A method as claimed in claim 1 wherein the particles contain a predetermined dopant atomic species, the energy of the particles is sufficient to implant the dopant atomic species to a predetermined depth, the dose of particles is sufficient to produce a predetermined dopant concentration in the substrate, and the pulse duration of the beam of particles is sufficiently short to anneal the implanted region of the substrate.

10. A method as claimed in claim 1 wherein the particles contain a predetermined dopant species implanted with a predetermined energy that produces a doped region in the substrate extending to a doping depth, and thermal energy imparted by the particles has a diffusion length over the duration of the particle beam pulse that is less than 100 microns.

11. A method as claimed in claim 1 wherein the particles include at least one atom of boron (B), aluminum (Al), gallium (Ga), indium (In), arsenic (As), phosphorus (P), or antimony (Sb).

12. A method as claimed in claim 1 wherein the particles have the same valency as the substrate.

13. A method as claimed in claim 12 wherein the substrate is composed of silicon, and the particles include at least one atom of silicon (Si) or germanium (Ge).

14. A method as claimed in claim 1 wherein the particles are produced from a gas including at least one of hydrogen (H), helium (He), neon (Ne), nitrogen (N), oxygen (O), argon (Ar), xenon (Xe), and krypton (Kr).

15. A method as claimed in claim 1 wherein the particles include alpha particles.

16. A method as claimed in claim 1 wherein the energy of the particles is in a range from one-tenth (0.1) to one-hundred (100) kilo-electron-Volts.

17. A method as claimed in claim 1 wherein the energy of the particles is in a range from five (5) to seven (7) kilo-electron-Volts.

18. A method as claimed in claim 1 wherein the particle dose ranges from 10^{12} to 10^{18} particles per square centimeter at the surface of the substrate.

19. A method as claimed in claim 1 wherein the dose of particles ranges from 5×10^{12} to 5×10^{13} particles per square centimeter at the substrate.

20. A method as claimed in claim 1 wherein the energy dose of a single pulse of the particles is from one-tenth (0.1) to one (1.0) Joules/cm^2.

21. A method as claimed in claim 1 wherein the substrate includes at least one relatively disordered region in contact with a relatively ordered region of the substrate, and the energy of the particles is sufficient to heat the disordered region through to the ordered region so that the disordered region recrystallizes with the same crystallographic orientation as the relatively ordered region of the substrate.

22. A method as claimed in claim 1 wherein the substrate includes a semiconductor material.

23. A method as claimed in claim 1 wherein the substrate includes silicon.

24. A method as claimed in claim 1 wherein the substrate includes a relatively thin layer of semiconductor material on an insulative material.

25. A method as claimed in claim 1 wherein the substrate includes dopant atoms and the particle beam heats and melts the substrate so that the dopant atoms are incorporated into the substrate on recrystallization.

26. At least one integrated transistor device formed on a semiconductor substrate and having source and drain regions annealed by a pulsed particle beam having a time duration of 10^{-4} seconds or less.

27. A method comprising the steps of:

a) generating a pulse of charged particles having a time duration between 10^{-7} and 10^{-4} seconds;

b) accelerating the charged particles toward a substrate; and

c) concentrating the charged particles to increase the flux of the particles to produce a dose sufficient to anneal a region of the substrate in the duration of the pulse.

28. A method as claimed in claim 27 wherein steps (a) - (c) are performed with a multicusp generator.

29. A method as claimed in claim 27 wherein the charged particles include electrons.

30. A method as claimed in claim 27 wherein the charged particles include protons.

31. A method as claimed in claim 27 wherein the charged particles include ions, the method further comprising the step of:

d) ionizing a gas to produce the ions.

32. A method as claimed in claim 31 wherein the ions include a predetermined dopant atomic species contained in the ionized gas.

33. A method as claimed in claim 32 wherein energies of the ions are sufficient to dope the implanted region of the substrate to a predetermined depth.

34. A method as claimed in claim 32 wherein the dose of implanted ions is sufficient to produce a predetermined dopant concentration in the substrate.

35. A method as claimed in claim 31 wherein the dose, energy, and pulse duration of the particles is sufficient to anneal the doped region of the substrate.

36. A method as claimed in claim 31 wherein the ions include at least one atom of boron (B), aluminum (Al), gallium (Ga), indium (In), arsenic (As), phosphorus (P), or antimony (Sb).

37. A method as claimed in claim 31 wherein the ions include at least one of silicon (Si) and germanium (Ge).

38. A method as claimed in claim 31 wherein the ions are produced from a gas including at least one of hydrogen (H), helium (He), neon (Ne), nitrogen (N), oxygen (O), argon (Ar), xenon (Xe), and krypton (Kr).

39. A method as claimed in claim 27 wherein the charged particles include alpha particles.

40. A method as claimed in claim 27 wherein the energy of the charged particles is in a range from one-tenth (0.1) to one-hundred (100) kilo-electron-Volts.

41. A method as claimed in claim 27 wherein the energy of the charged particles is in a range from five (5) to seven (7) kilo-electron-Volts.

42. A method as claimed in claim 27 wherein the particle dose ranges from 10^{12} to 10^{18} particles per square centimeter at the surface of the substrate.

43. A method as claimed in claim 27 wherein the dose of particles ranges from 5×10^{12} to 5×10^{13} particles per square centimeter.

44. A method as claimed in claim 27 wherein the particles are applied to the substrate in a pulse, and the pulse duration of the particles is from 10^{-9} to 10^{-4} seconds.

45. A method as claimed in claim 27 wherein the particles are applied to the substrate in a pulse, and the pulse duration of the particles is from 5×10^{-7} to 5×10^{-6} seconds.

46. A method as claimed in claim 27 wherein the energy dose can be in a range from one-tenth (0.1) to one (1.0) Joules/cm^2.

47. A method as claimed in claim 27 wherein the substrate includes an amorphous region positioned in contact with the substrate and the charged particles heat the amorphous region sufficiently trigger recrystallization of the amorphous region through to the crystalline substrate so that the new crystalline material has the same crystallographic orientation as the substrate.

48. A method as claimed in claim 27 wherein the substrate includes a semiconductor material.

49. A method as claimed in claim 27 wherein the substrate includes silicon.

50. A method as claimed in claim 27 wherein the substrate includes a relatively thin layer of semiconductor material on an insulative material.

Sub C1

51. A method as claimed in claim 27 wherein the substrate includes dopant atoms and the particle beam heats and melts the substrate so that the dopant atoms are incorporated into the substrate so as to be electrically-active upon cooling and recrystallization of the substrate.

Sub D7

52. A method comprising the step of implanting dopant atoms into a semiconductor substrate with sufficient energy so that the dopant atoms are distributed to a predetermined depth from the surface of the substrate, the energy, dose and pulse duration imparted by the dopant atoms sufficient to raise the temperature of the substrate atoms to permit annealing of the dopant atoms.

Sub C2

53. A method comprising the steps of annealing at least one integrated device formed in a semiconductor substrate with a pulsed beam of particles having a duration between 10^{-10} seconds and 10^{-4} seconds.

Sub D7

54. A method as claimed in claim 53 wherein the particles include electrons.

55. A method as claimed in claim 53 wherein the particles include protons.

56. A method as claimed in claim 53 wherein the particles include ions.

57. A method as claimed in claim 53 wherein the particles include a predetermined species of dopant atom, the energies of the particles are sufficient to implant to the predetermined depth, and the energy, dose, and pulse duration are

predetermined to anneal the implanted region of the substrate.

Sub A1

58. A method as claimed in claim 53 wherein the ions are implanted with an energy that produces a doped region in the substrate extending to a predetermined depth and the thermal energy imparted by the ions has a diffusion length, during the duration of the pulse, that is less than one-hundred (100) microns.

59. A method as claimed in claim 53 wherein the ions include at least one boron (B), aluminum (Al), gallium (Ga), indium (In), arsenic (As), phosphorus (P), and antimony (Sb).

Sub D7

60. A method as claimed in claim 53 wherein the particles include at least one atom of silicon (Si) and germanium (Ge).

61. A method as claimed in claim 53 wherein the particles are produced from a gas including at least one of hydrogen (H), helium (He), neon (Ne), nitrogen (N), oxygen (O), argon (Ar), xenon (Xe), and krypton (Kr).

62. A method as claimed in claim 53 wherein the particles include alpha particles.

63. A method as claimed in claim 53 wherein the energy of the particles is in a range from one-tenth (0.1) to one-hundred (100) kilo-electron-Volts.

64. A method as claimed in claim 53 wherein the energy of the particles is in a range from five (5) to seven (7) kilo-electron-Volts.

65. A method as claimed in claim 53 wherein the particle dose ranges from 10^{12} to 10^{18} particles per square centimeter at the surface of the substrate.

66. A method as claimed in claim 53 wherein a dose of particles ranges from 5×10^{12} to 5×10^{13} particles per square centimeter.

67. A method as claimed in claim 53 wherein the particles are applied to the substrate in a pulse, and the pulse duration of the particles is from 10^{-9} to 10^{-4} seconds.

68. A method as claimed in claim 53 wherein the particles are applied to the substrate in a pulse, and the pulse duration of the particles is from 5×10^{-7} to 5×10^{-6} seconds.

69. A method as claimed in claim 53 wherein the dosage of energy can be from one-tenth (0.1) to one (1.0) Joules/cm^2.

70. A method as claimed in claim 53 wherein the substrate includes at least one relatively disordered region in contact with a relatively ordered region of the substrate, and the energy of the particles, the dose and the pulse duration is sufficient to heat the disordered region through to the ordered region so that the disordered region recrystallizes with the same crystallographic orientation as the relatively ordered region of the substrate.

71. A method as claimed in claim 53 wherein the substrate includes a semiconductor material.

72. A method as claimed in claim 53 wherein the substrate includes silicon.

73. A method as claimed in claim 53 wherein the substrate includes a relatively thin layer of semiconductor material on an insulative substrate.

Sub D7

74. A method as claimed in claim 53 wherein the substrate includes dopant atoms and the particles heat and melt the substrate so that the dopant atoms are incorporated into the crystalline structure of the substrate so as to be electrically-active upon cooling of the substrate.